Sana'a University
Faculty of Engineering
Mechatronics Department

Encoder sensor

MECHATRONICS SYSREM DSIGN

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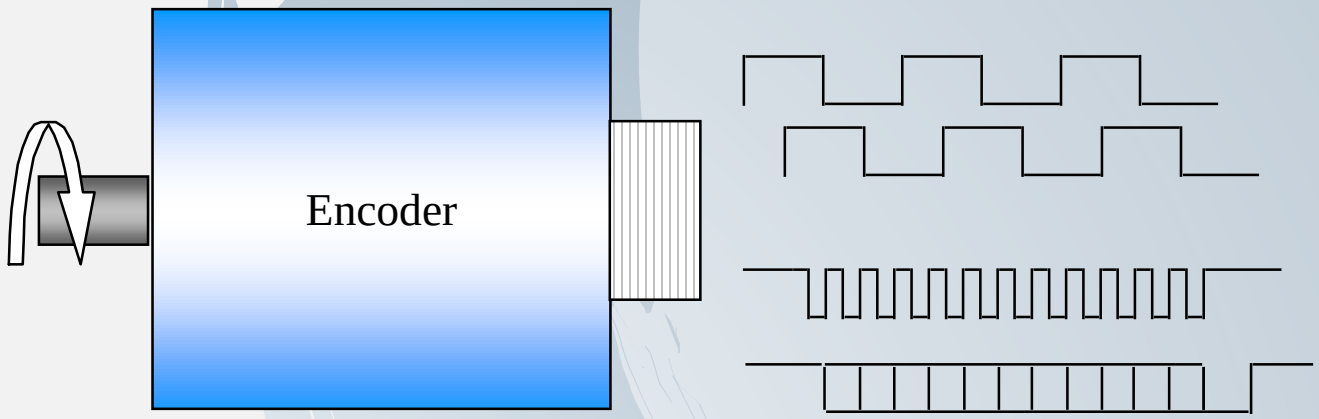
Encoder Definitions

What is an encoder?

It is an electro-mechanical device (sensor), which can detect and convert mechanical motion to an analogue or digital coded output signal.

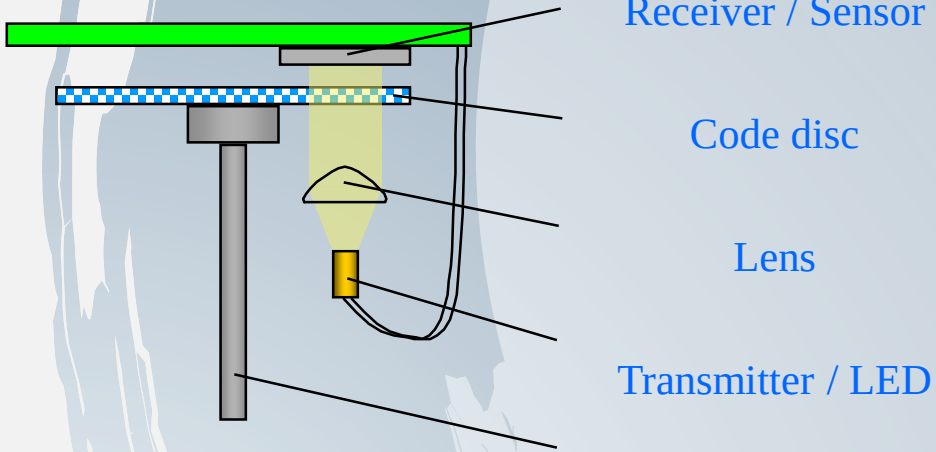
Encoders are used to determine the position, velocity and direction of motor shaft speed and other mechanical motion.



Encoder Definitions

How is this accomplished?

As the code disc rotates, it shutters light from the LED and is received and transmitted as square\sine waveforms (into Analog or Digital Signal).



Types of Encoders

Linear

Convert Linear distance movement (monitors the load's actual position)

rotary

Convert Angular Position (monitors speed and direction)

absolute

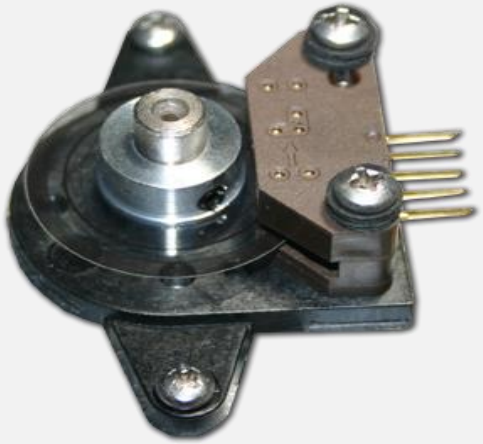
Provides a unique value for every shaft or linear position

incremental

Produces a train of electrical pulses or increments

Incremental Encoders

- Signals can be square or sinusoidal waves
- Store the data in an external buffer or counter (counting from zero)
- Resolutions are represented by the number of pulses per revolution, (PPR) and represent the number of high pulses.
- Typically used for speed or applications that do not require absolute position
- simpler and cheaper
- signals in two channels, A and B, out-of-phase by 90°



How do Incremental Encoders Work?

- utilize a transparent disk which contains opaque sections that are equally spaced to determine movement. A light emitting diode is used to pass through the glass disk and is detected by a photo detector. This causes the encoder to generate a train of equally spaced pulses as it rotates. The output of incremental rotary encoders is measured in pulses per revolution which is used to keep track of position or determine speed.
- **NOTE:** Incremental rotary encoders are not as accurate as absolute rotary encoders due to the possibility of interference or a misread.

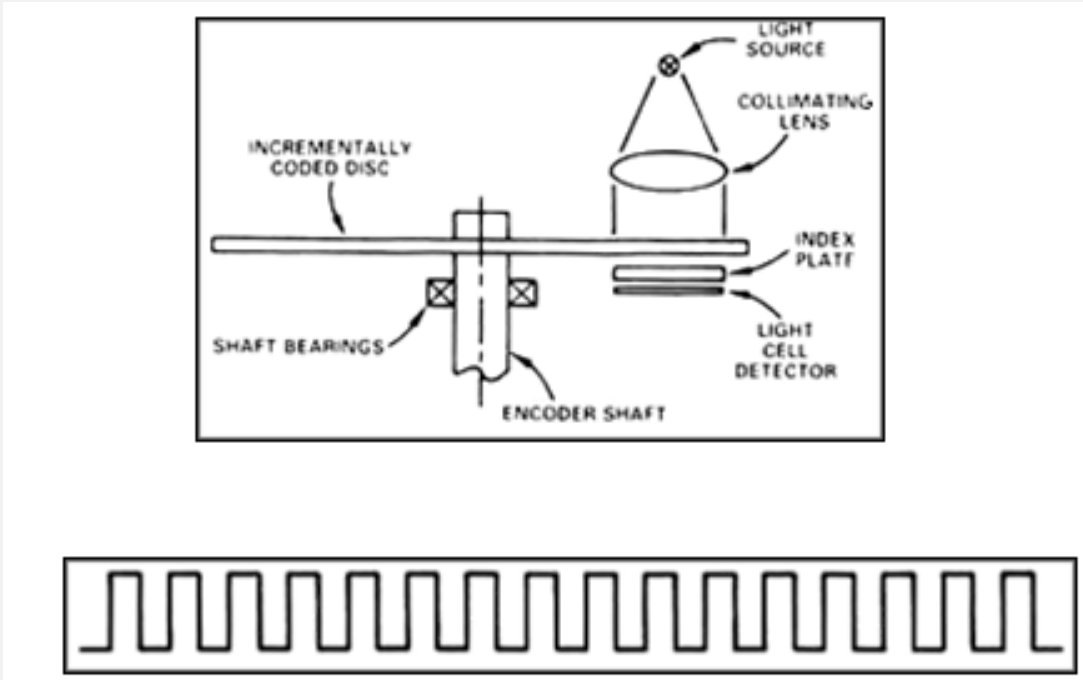
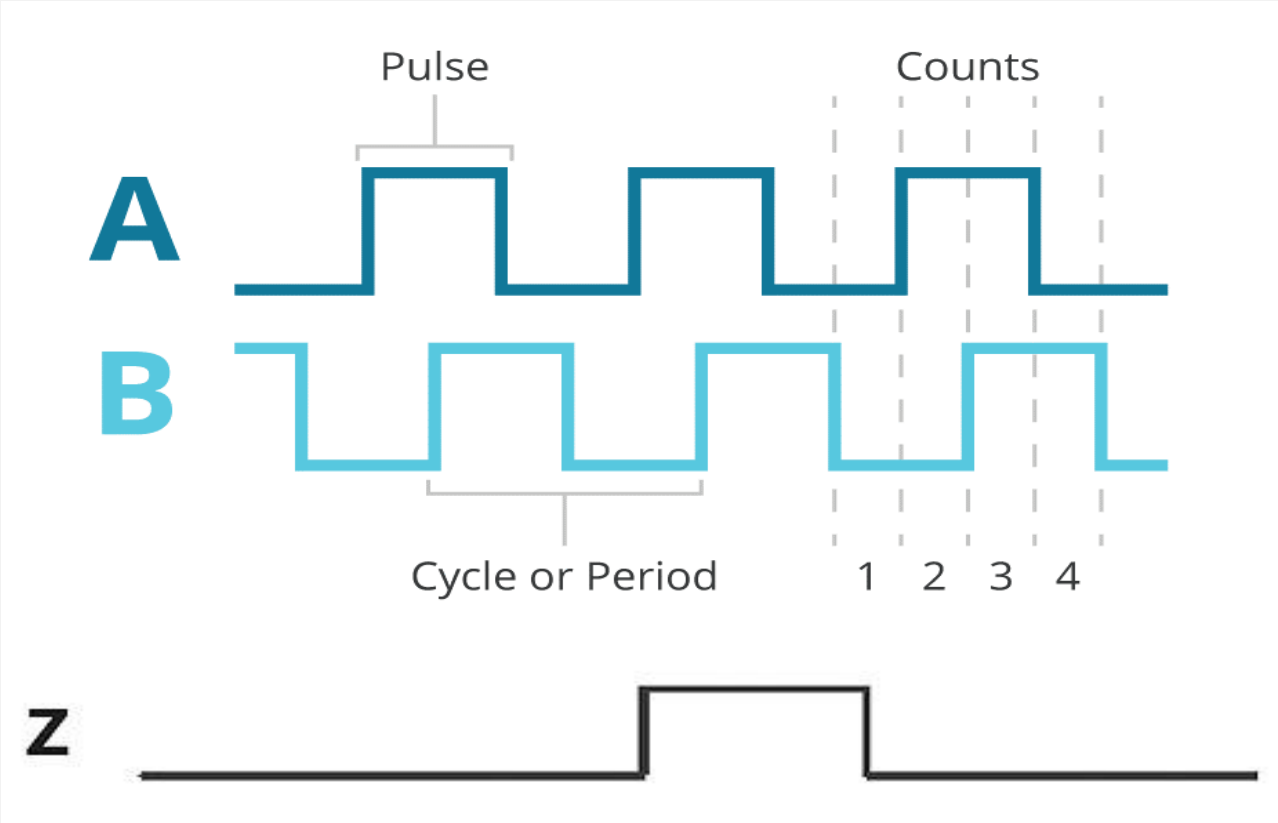


Figure 5: Pulse Train Produced from Incremental Encoder

What is quadrature output?

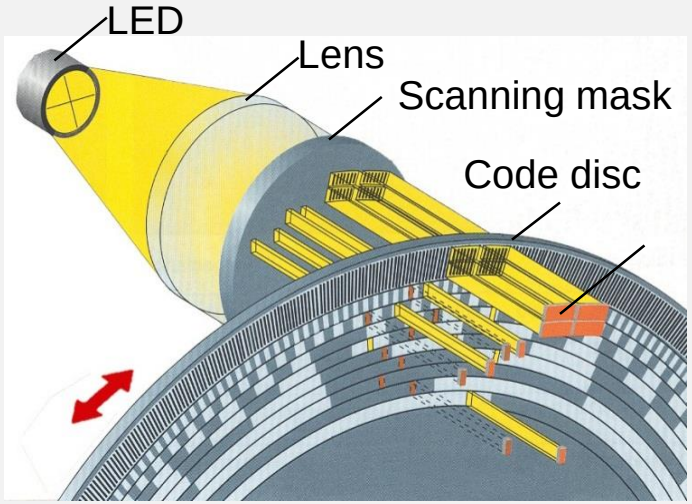
- Dual channel to detect motion & direction
- In a rotary encoder, quadrature output uses two different channels (A and B) separated by 90 degrees of phase shift to increase resolution. Each of these two outputs can either be ON or OFF, resulting in four different “states” for each segment of resolution.
- An encoder with n of slots has 4*n different states
- **Z-pulse or the Index Channel**
  zero position pulse

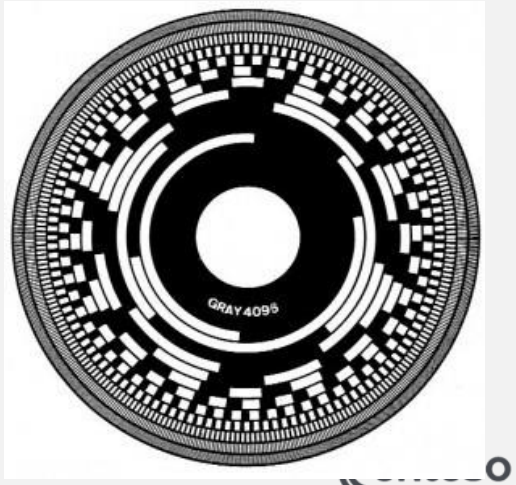


Absolute Encoders

- Can retain their position after a power off (non-volatile memory).
- Used in applications were absolute position information is necessary.
- have an option of 16 bits (65536) per revolution (turn) higher resolution.
- the output is specified in a binary format.
- More complex and expensive.

- **NOTE:** The construction of these two types is quite similar however they differ in physical properties and the interpretation of movement.





How do Absolute Encoders Work?

- Absolute encoders utilize stationary mask in between the photodetector and the encoder disk as shown below. The output signal generated from an absolute encoder is in digital bits which correspond to a unique position. The bit configuration is produced by the light which is received by the photodetector when the disk rotates. The light configuration received is translated into gray code. As a result, each position has its own unique bit configuration.

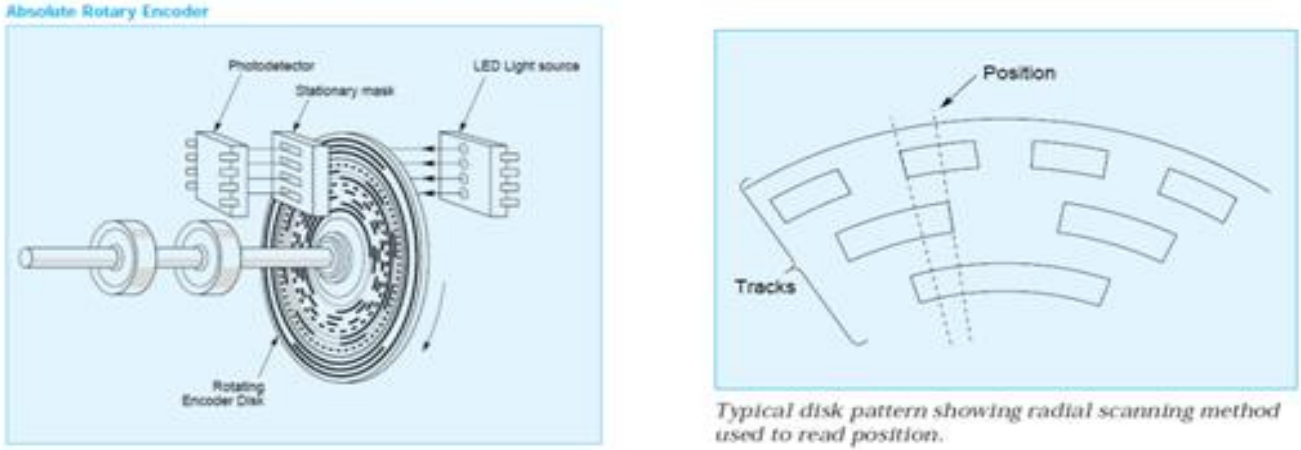
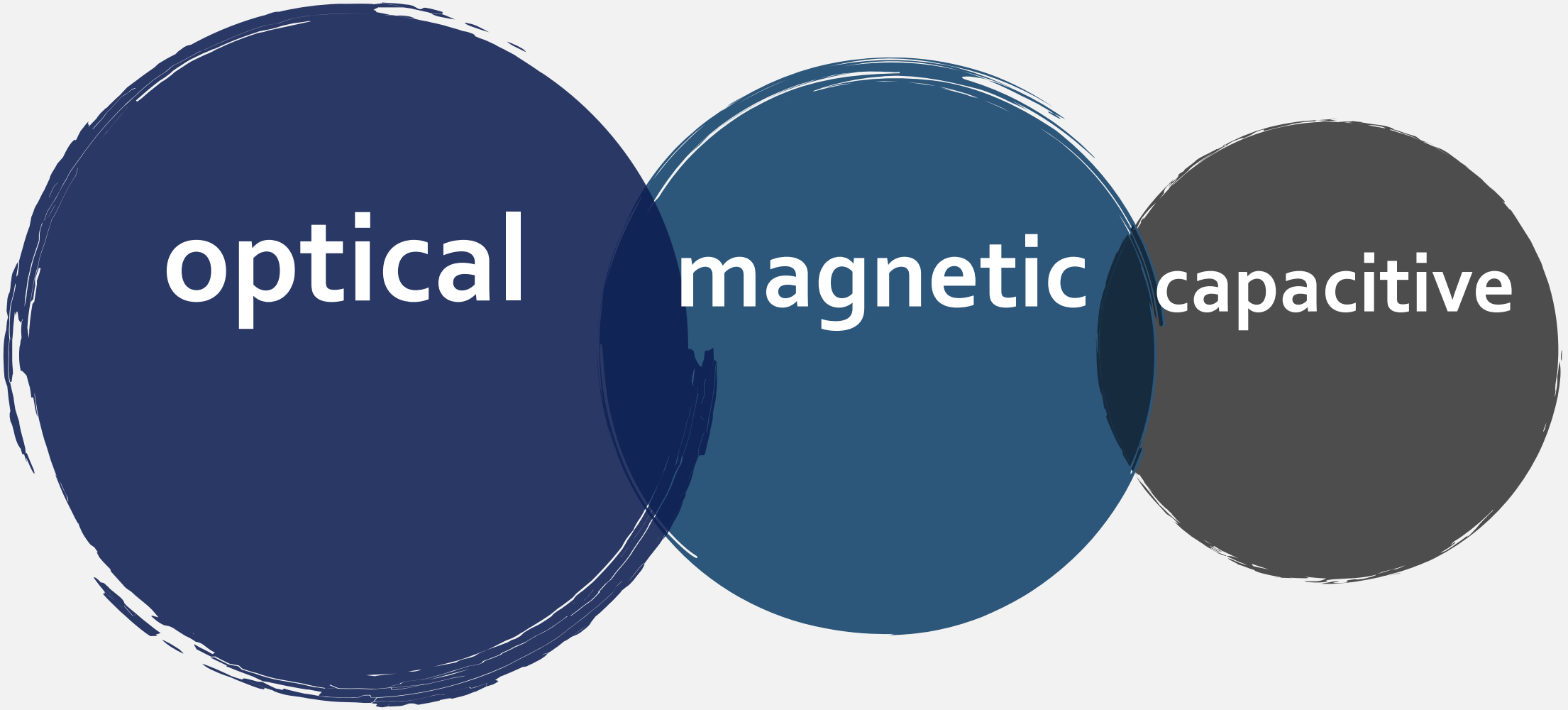


Figure 6: Components of Absolute Encoder

Encoder technologies

The position information can be determined using one of three technologies: optical, magnetic or capacitive

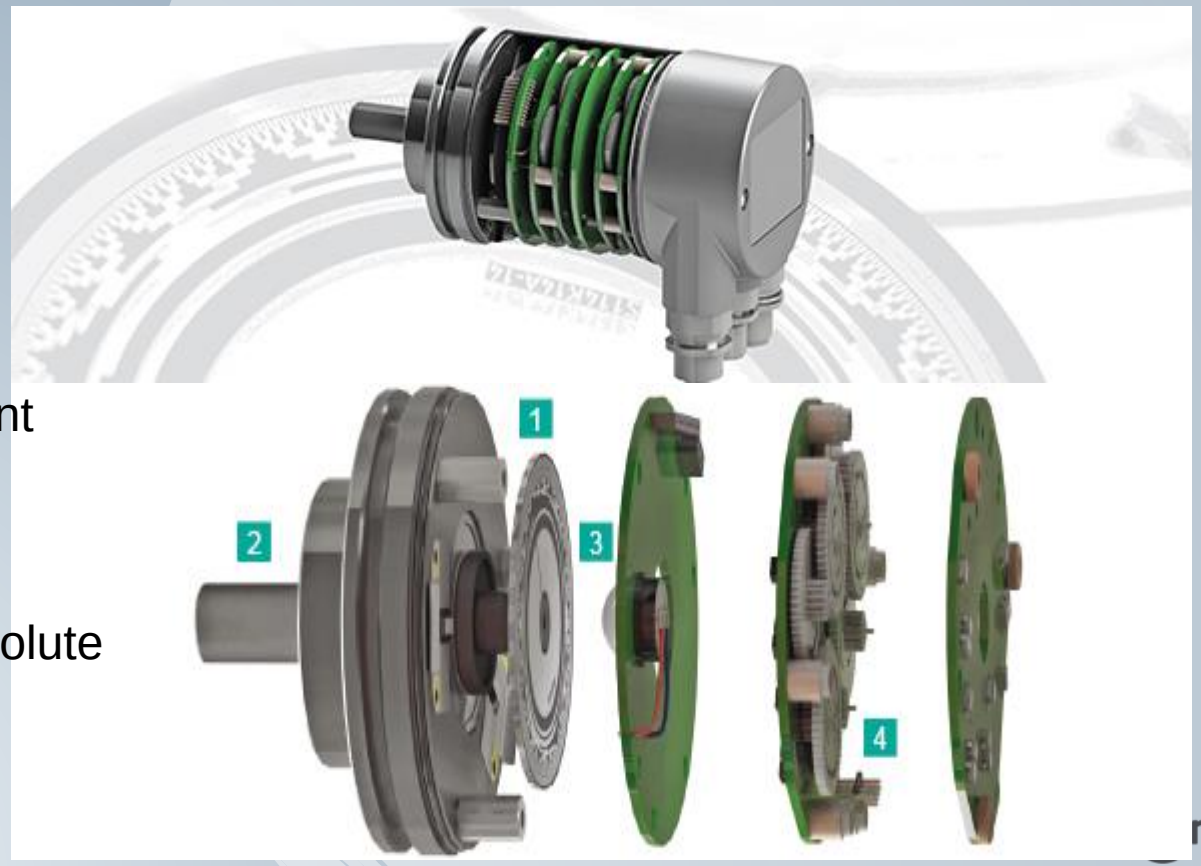


Optical encoder

Optical encoders are the most accurate of the standard styles of encoders, and the most commonly used in industrial automation applications.

optical encoders, which use a light source and a photo-detector to determine position, are best for applications that require sub-micron resolution. But because their operation is based on detecting light, they are very sensitive to dirt and debris

1. code disk
2. encoder shaft
3. Infrared light (LED)
4. gear train



Advantages of Optical Encoders

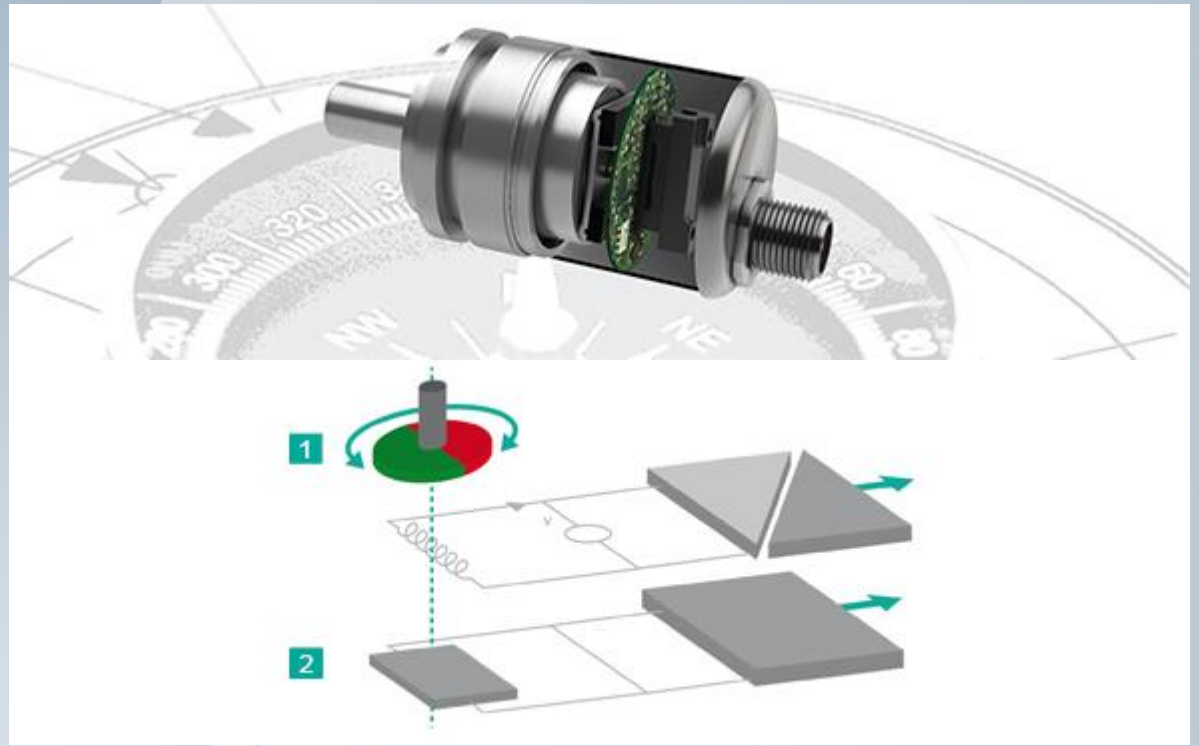
- High resolution and accuracy along with excellent dynamic response
- For use in areas with high magnetic fields
- No risk of these devices losing track of their absolute position
- No backup batteries required

Magnetic encoder

Magnetic encoders are more rugged than optical encoders, but have less resolution and accuracy. They are often used in environments with excessive dirt, steam, vibrations .

magnetic encoders use a magnetic reader head and a magnetic scale to determine position. Because they rely on a magnetic field rather than light detection, these encoders are mostly unaffected by dust, debris, or oil contamination.

1. code disk
2. encoder shaft
3. Infrared light (LED)
4. gear train

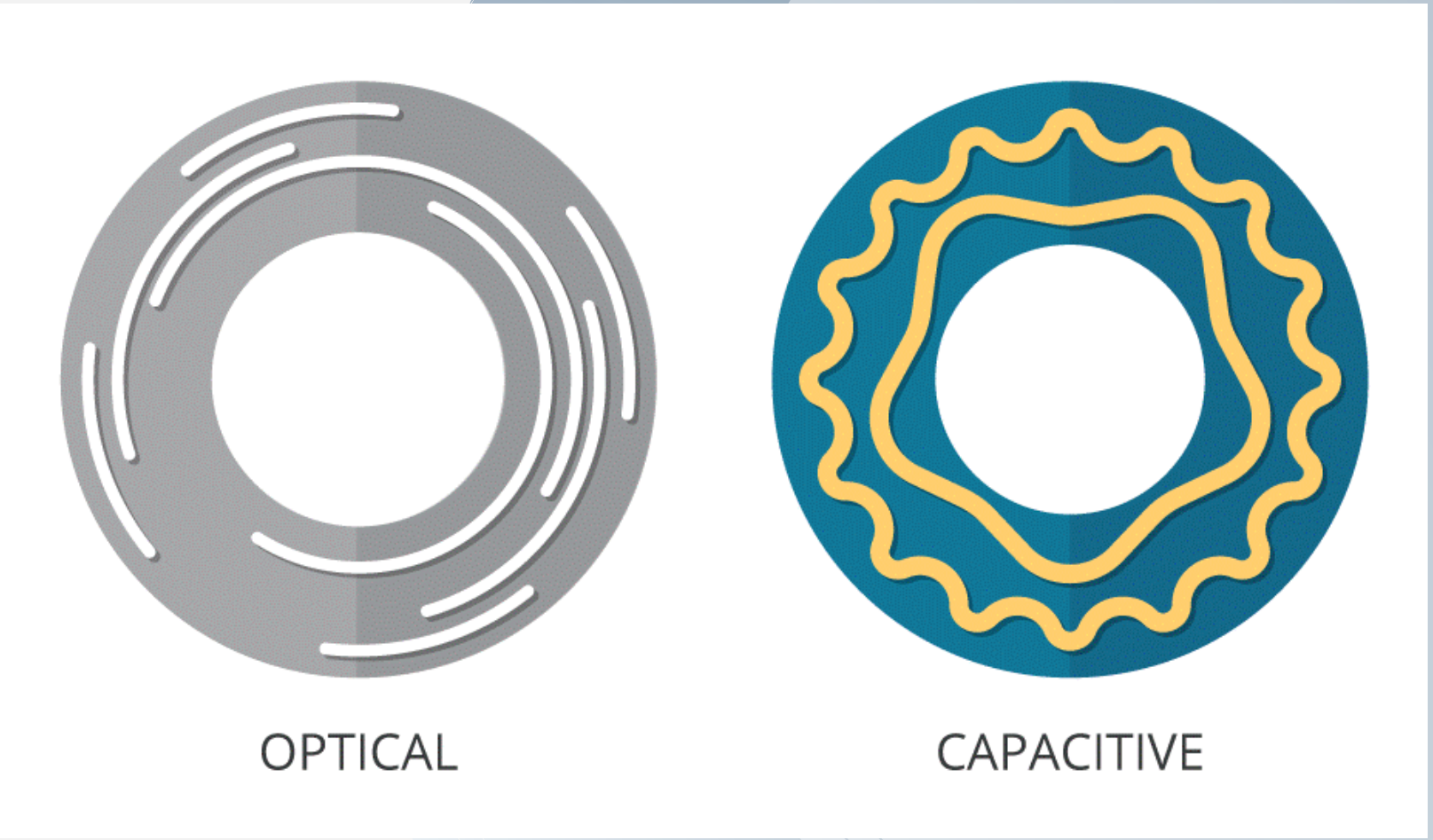


Advantages of Magnetic Encoders

- Robust and durable
- Mechanically simple and economical − no battery, no gear
- Compact design for installation in small spaces

Capacitive encoder

Capacitive encoders are relative newcomers to industrial automation. These encoders are as rugged as magnetic encoders, but also do not achieve the high resolution and accuracy of optical encoders.



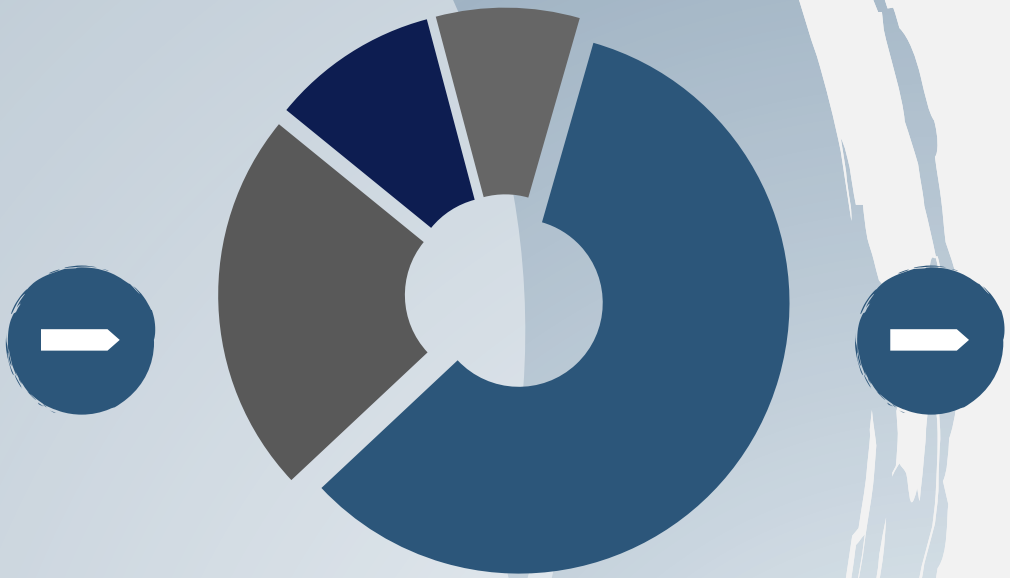
How to Select an Encoder

There are several important criteria involved in selecting the proper encoder:

- Encoder for Positioning >> an encoder with a number of pulses higher than 360°
- Encoder for High-Precision Positioning >> an optical encoders
- Encoder for Positioning with Mechanics >> a magnetic encoder
- Encoder for High-Speed Control (> 500 RPM) >> an encoder with a moderate or low number of states and a high speed rating
- Encoder for Low-Speed Control >> an encoder with a high or very high number of states in combination with a fast controller.

Advantages and Disadvantages of an Encoder

- Highly reliable and accurate
- Low-cost feedback
- High resolution
- Integrated electronics
- Fuses optical and digital technology
- Can be incorporated into existing applications
- Compact size



- Subject to magnetic or radio interference (Magnetic Encoders)
- Direct light source interference (Optical Encoders)
- Susceptible to dirt, oil and dust contaminates

Formulas

encoder CPR frequency and the speed of the motor (RPM)

f = (cycles/rev)*(rev/sec)/1000 = kHz

N = f x 60 / CPR where:

RPM = Revolution per Minute

N = Motor speed (revolution per minutes)
f = Encoder counts frequency (Hz)
CPR = Number of counts per revolution (4 times the number of lines/pulses per revolution)

Resolution

can be given in number of bits or degrees

- Absolute

  Resolution = $360°/(2^N)$

  N = number of encoder bits (number of tracks)

- Incremental

  Resolution = 360/N

  N = number of windows on code disk

Distance Conversion:

(PPR) / (2*pi*radius of shaft) = pulses per inch
(Pulses per inch)^-1 = inch per pulse

Where are Encoders Used?

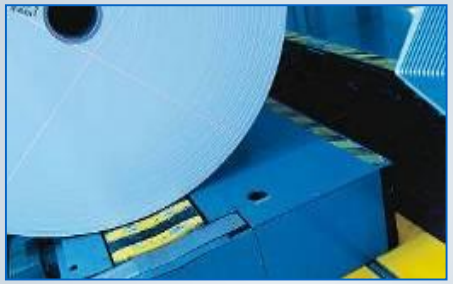
Encoders have become a vital source for many applications requiring feedback information. Whether an application is concerned with speed, direction or distance, an encoders vast capability allow users to utilize this information for precise control. With the emergence of higher resolutions, ruggedness, and lower costs, encoders have become the preferred technology in more and more areas. Today, encoder applications are all around us. They are utilized in printers, automation, medical scanners, and scientific equipment.

Automotive
Consumer Electronics and Office Equipment
Industrial
Medical
Military
Scientific Instruments

Fields of applications

Packaging

Print & Paper



Wood industry

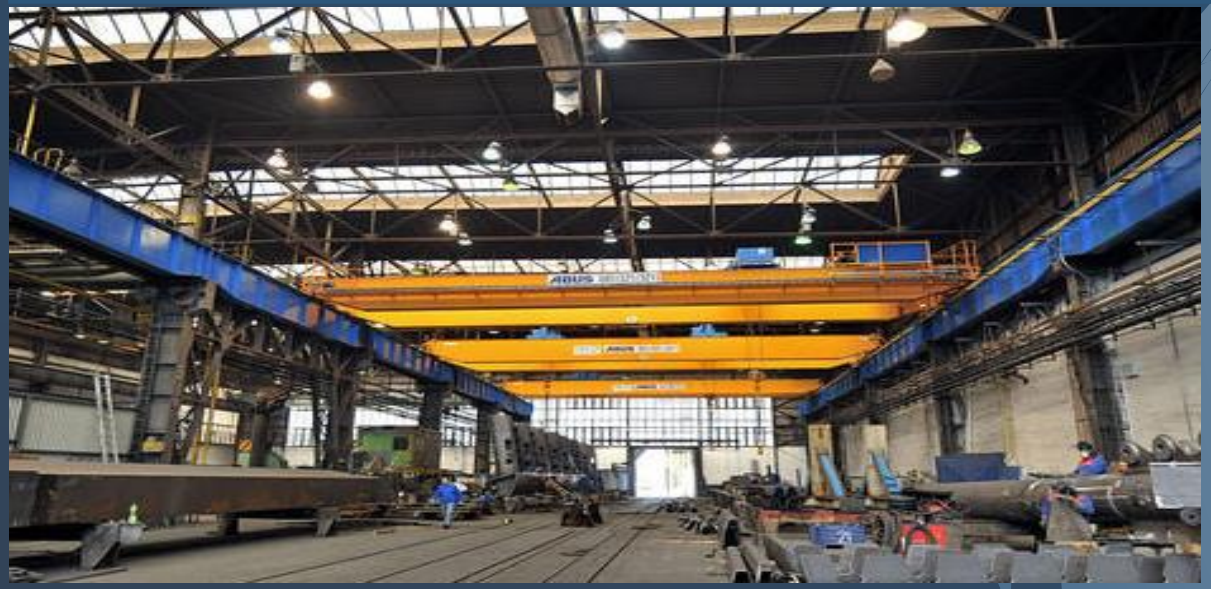
Machine Tooling

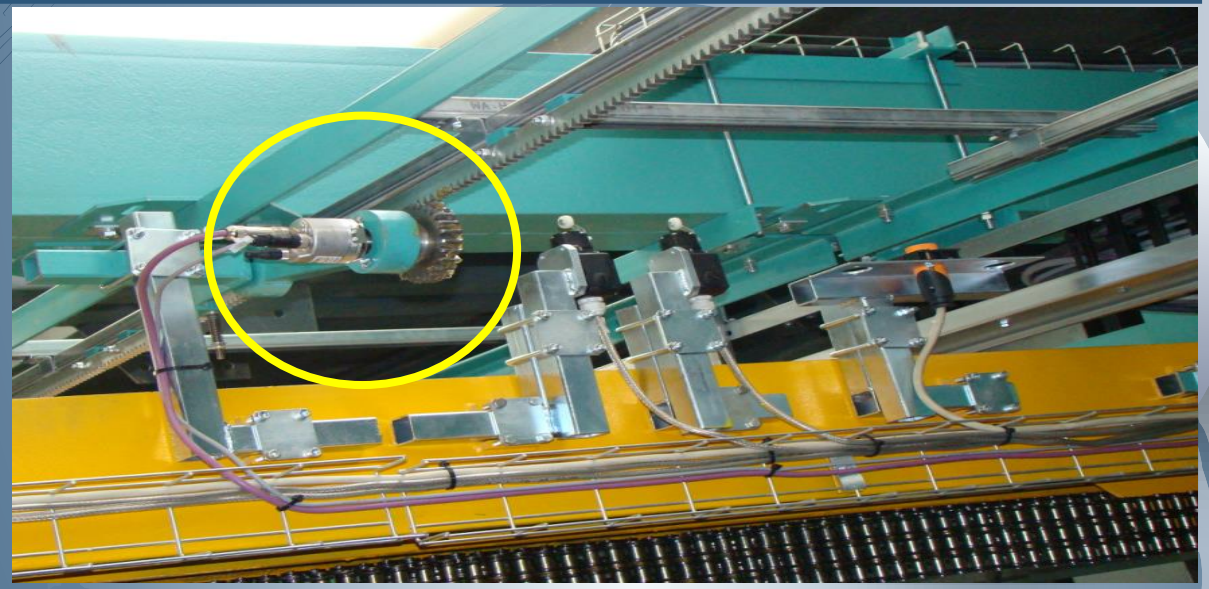
Automotive

Ports & Cranes

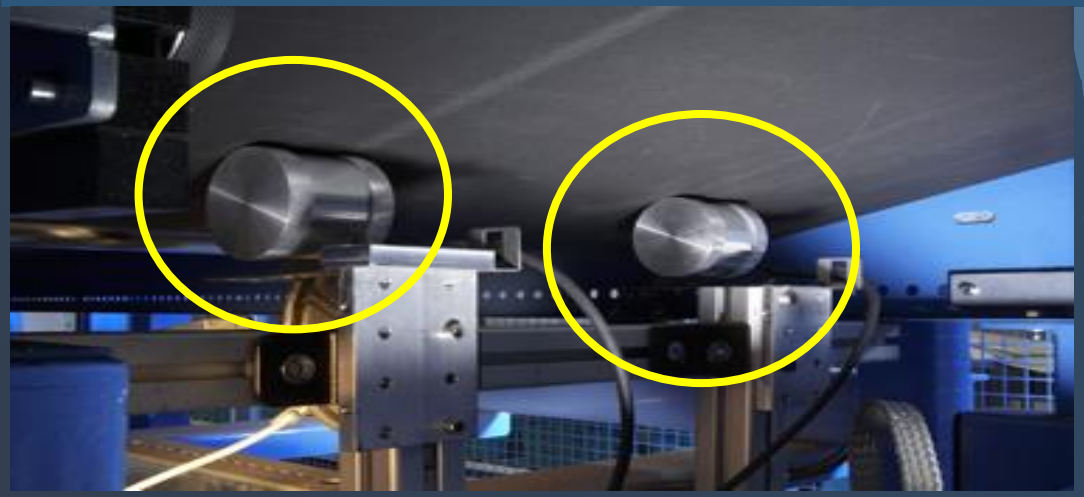
Handling

OVERHEAD CRANE– AFM60 EtherNet/IP used to track position of crane

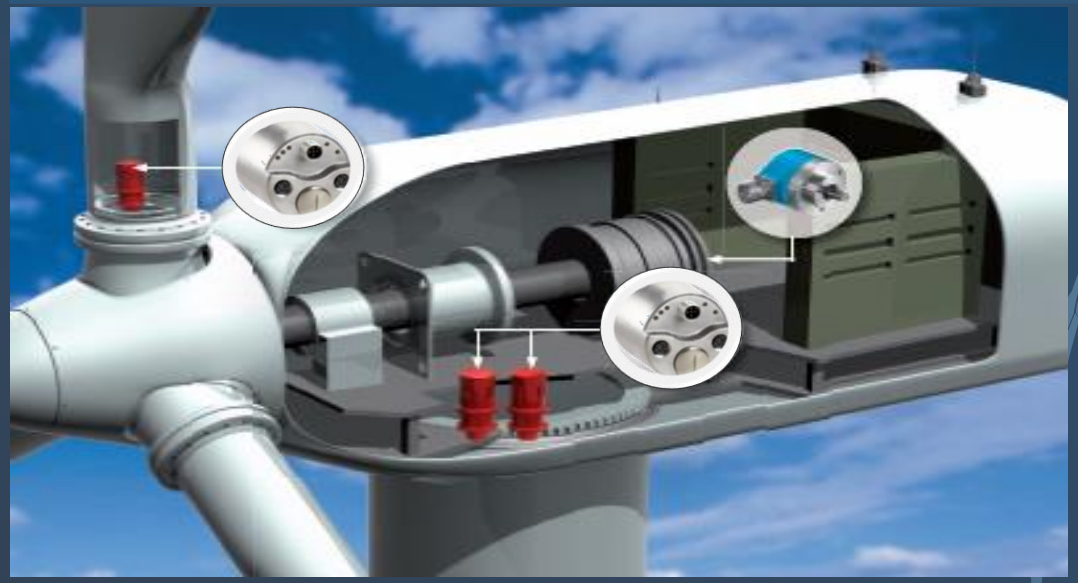




CONVEYORS – DKV60 used to track speed of conveyor



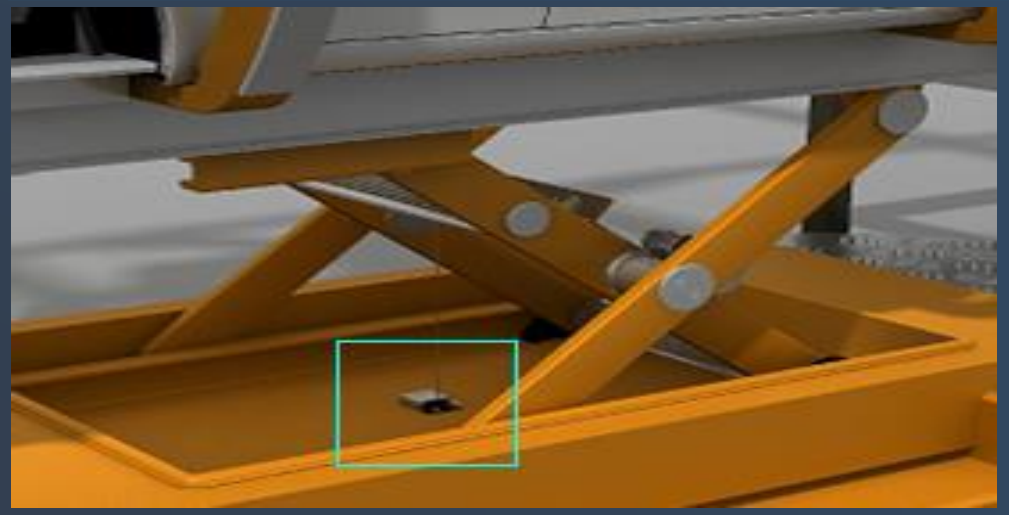
WIND TURBINE – Absolute encoder AFM60 for gandala and blade angle tracking

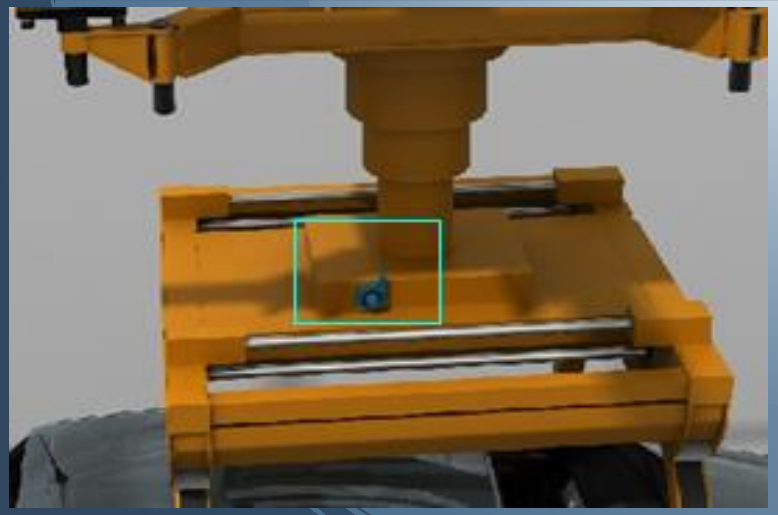


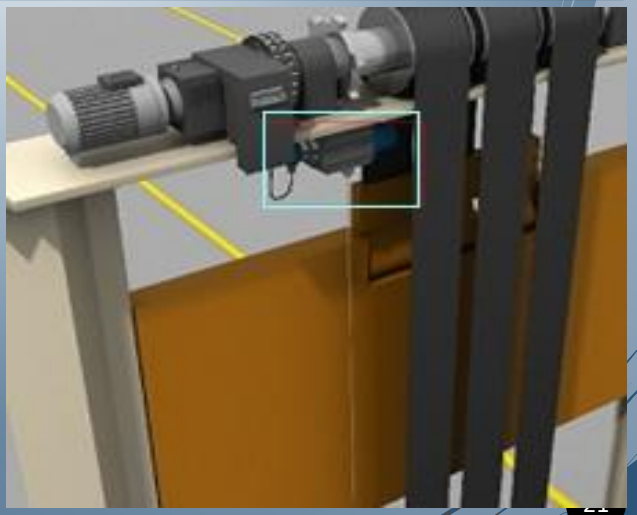
BOTTLING – Absolute encoder AFS60 to track position of fillers

STADIUM ROOF – Position with KH53 Linear Encoder

LIFT APPLICATIONS – Height and Width positioning using BGC Wiredraw Encoders








ABSOLUTE
VS
INCREMENTAL

Troubleshooting

Problem: No output
Solution: No output may be a result of various factors. Steps can be taken to ensure the proper functionality of the encoder. No mechanical movement results in any signal being output from the encoder. To correct this issue, observe if the encoder is rotating. Verify all wring between the encoder and the driver/controller is correct and the appropriate voltage supply is used. Having loose connections or improper voltage supply may not allow the encoder to function properly. Finally, ensure the correct signal type (e.g. open collector, pull-up, line driver or push-pull) is being used for your application. If the problem persists, swap encoders, if possible, to determine if the encoder is the issue.

Problem: Unable to find index pulse
Solution: The index pulse, or reference marker, is a once per revolution output of an encoder and is best found using an oscilloscope. Verify all the wiring between the encoder and the driver/controller is correct and the appropriate voltage supply is used. If that does not solve the issue, try lowering the RPM of the motor, as the driver/controller may not be able to identify the index pulse at very high RPM values.

Problem: Count output indicates incorrect direction
Solution: If the count output indicates an incorrect direction then check for the wire configuration. See if any wires are reversed. If they are reversed, simply swap wires.

Troubleshooting

NOTE: If your application is using index, reversing the wire configuration causes the reference alignment to also change. If so, please make the appropriate changes to your application.

Problem: Encoder is not rotating
Solution: When encoders are exposed in open environments, dust and debris particles may accumulate around the shaft. Simply clean the exposed area and ensure that there are not objects obstructing the encoder from rotating.

Problem: Noise Interference
Solution: To improve the noise immunity of encoders it is strongly advised that no other electrical equipment be nearby or be kept at a fair distance. Encoder cables should also be shielded and proper wires should be grounded to minimize electrical noise.

Problem: Distorted or incorrect output
Solution: Distorted or incorrect output can be any combination of loose wiring connections, encoder output not compatible with driver/controller, electrical noise or improper alignment. Check for wire connections, compatibility issues with the encoder and the driver/controller, alignment of the encoder and the shaft to solve this issue.

Summary

- **Encoder** - is a sensor of mechanical motion that generates digital signals in response to motion.

  Incremental Encoder - device that provides a train of pulses due in response to mechanical motion. The output of this encoder is in form of a square wave.

- **Absolute Encoder** - provides the shaft position in a bit configuration and is able to maintain or provide absolute position even after instances of power loss/failure.
- **Cycles Per Revolution (CPR)** - Cycles per revolution are the number of output pulses per complete revolution of the encoder disk
- **Pulses Per Revolution (PPR)** - the total number of pulses produced per full revolution of the encoder shaft.

  Resolution – number of line increments on a disk. Resolution for incremental encoders is often referred to as cycles per resolution and for absolute encoders it is in terms of bits.

- **Quadrature Encoder** - two output channels which are out of phase by 90 electrical degrees. From the phase difference, the direction of rotation can also be determined.

THANK YOU